Chemistry of Superheavy Elements

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Logo of NRC6 conference Aachen

Acknowledgements

A.B. Yakushev, J. Dvorak, A. Semchenkov et al.,

J.V. Kratz, N. Trautmann et al.,

M. Schädel, Ch.E. Düllmann, V.G. Pershina et al.,

H.W. Gäggeler, R. Eichler et al.,

K.E. Gregorich et al.,

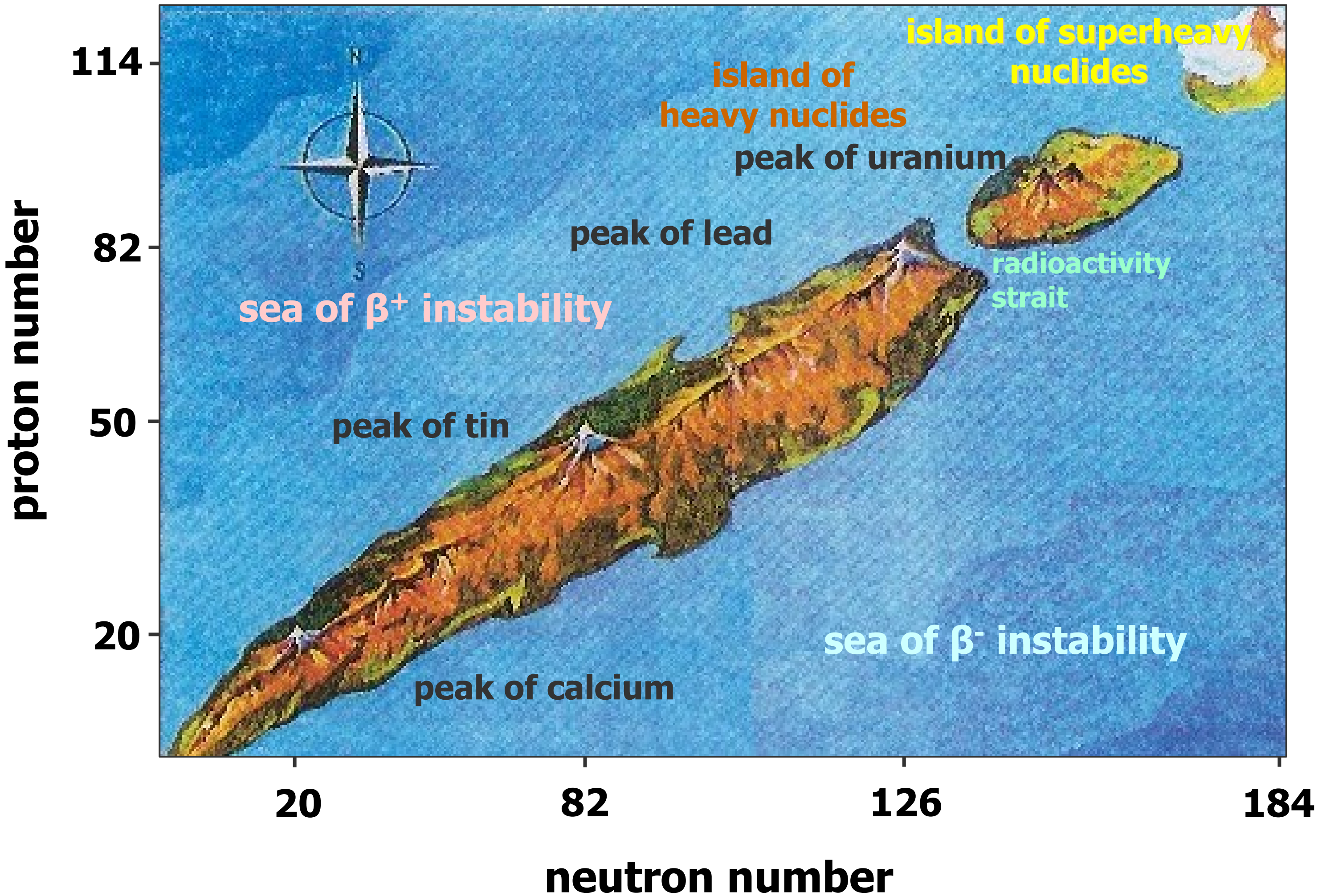
Y. Oganessian, A. Popeko, A. Yeremin et al.,

Where ends the periodic table of the elements?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	113	114	115	116		118

Lanthanides	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

The island of superheavy nuclides!



Superheavy Element Synthesis

1×10^{17} 2×10^{18} 5×10^{8} 1

GSI UNIversal Linear ACcelerator

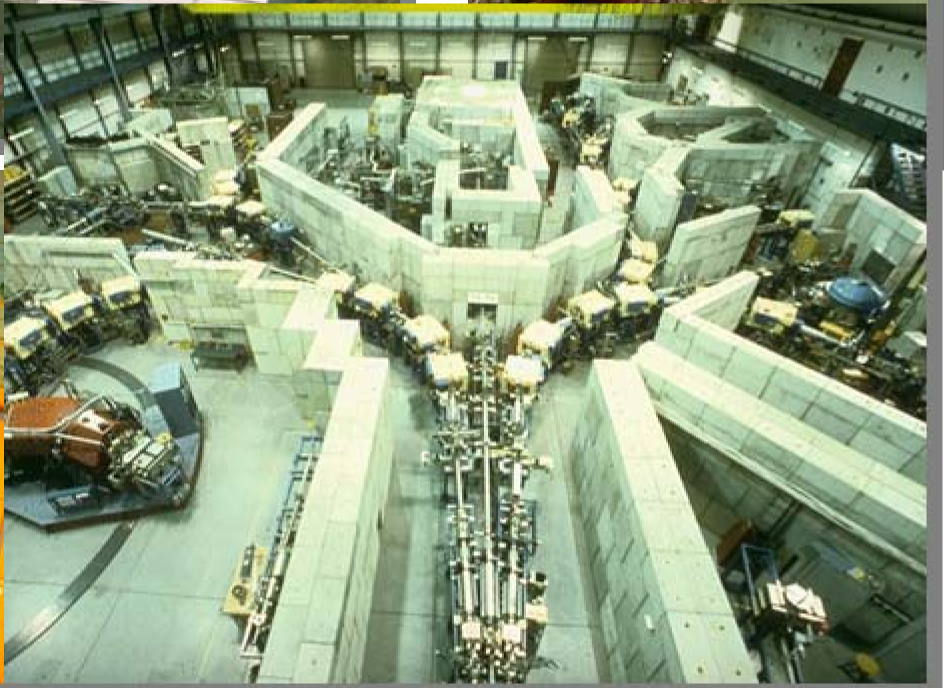


chart of nuclides (1998)
transactinides

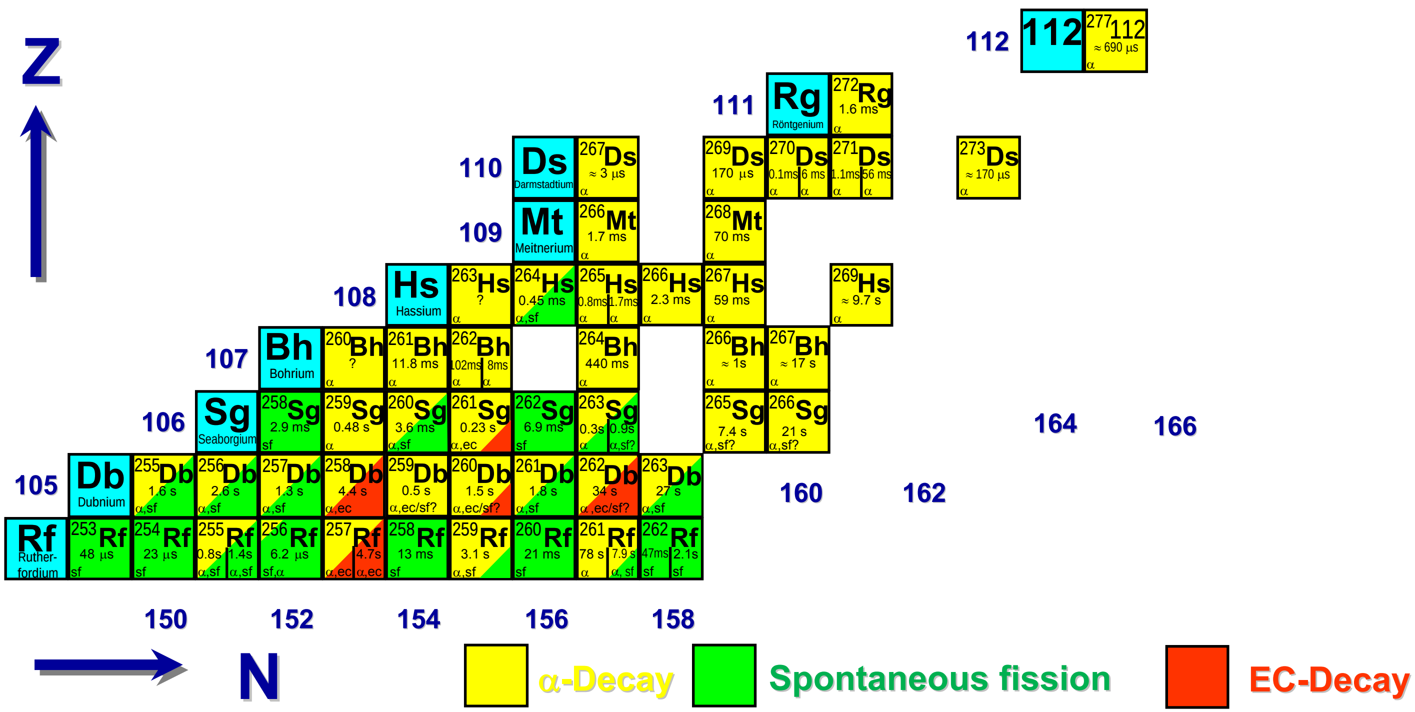
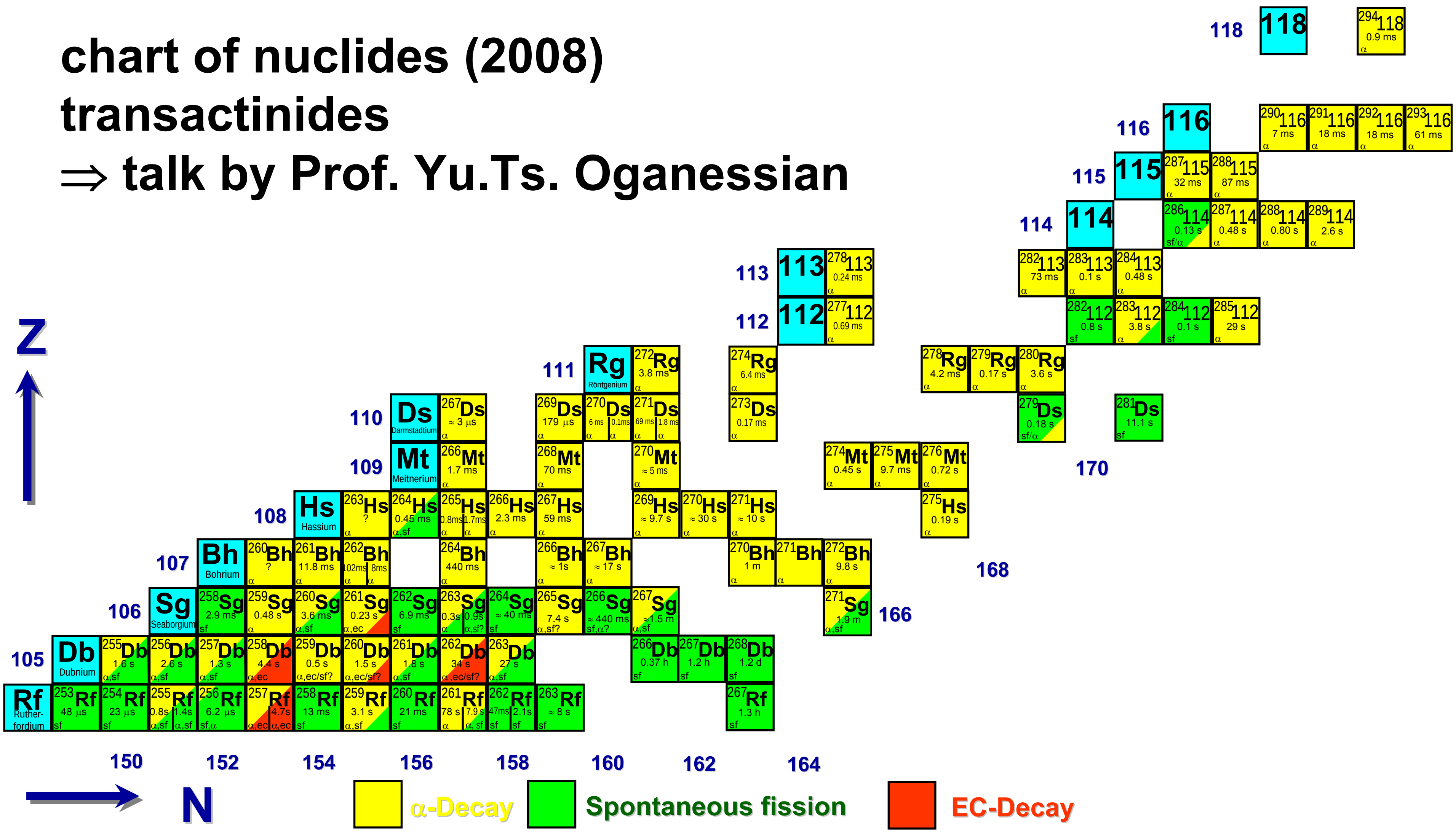
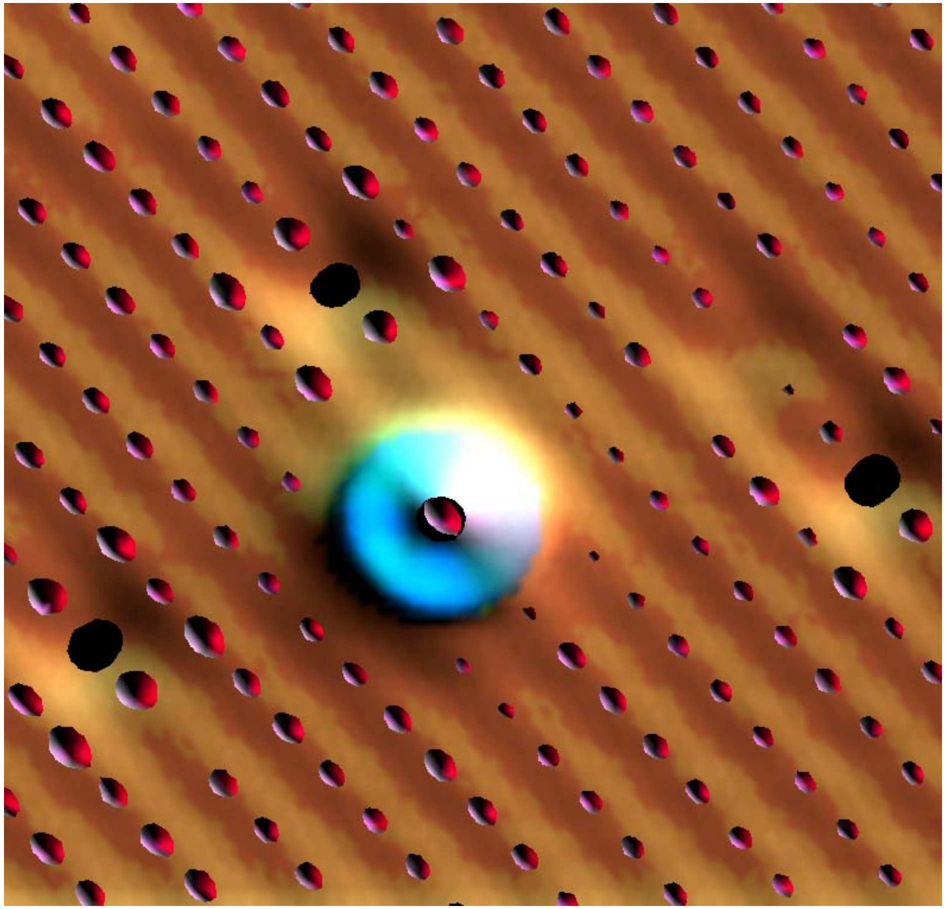


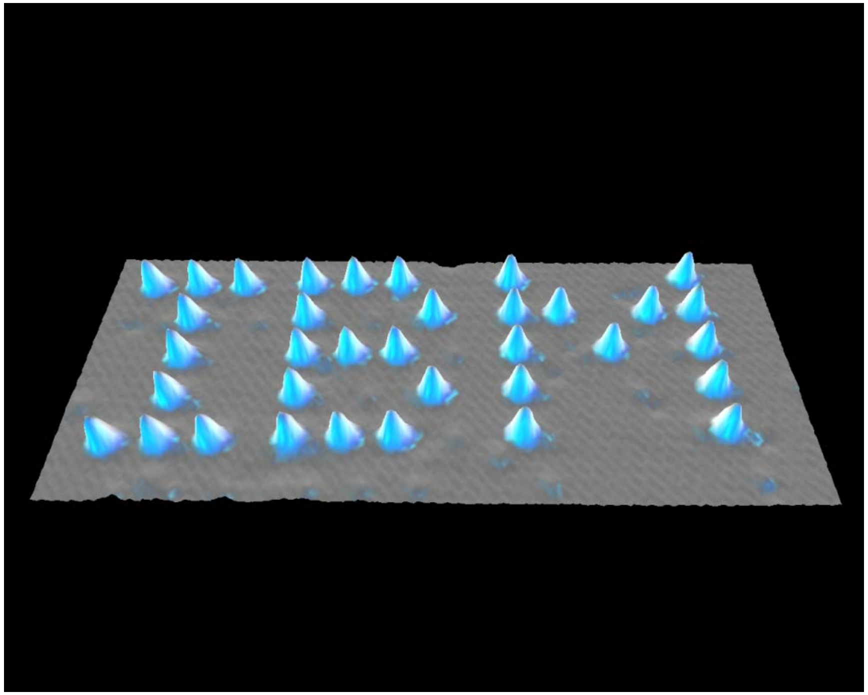
chart of nuclides (2008)
transactinides
⇒ talk by Prof. Yu.Ts. Oganessian



Manipulation of single atoms

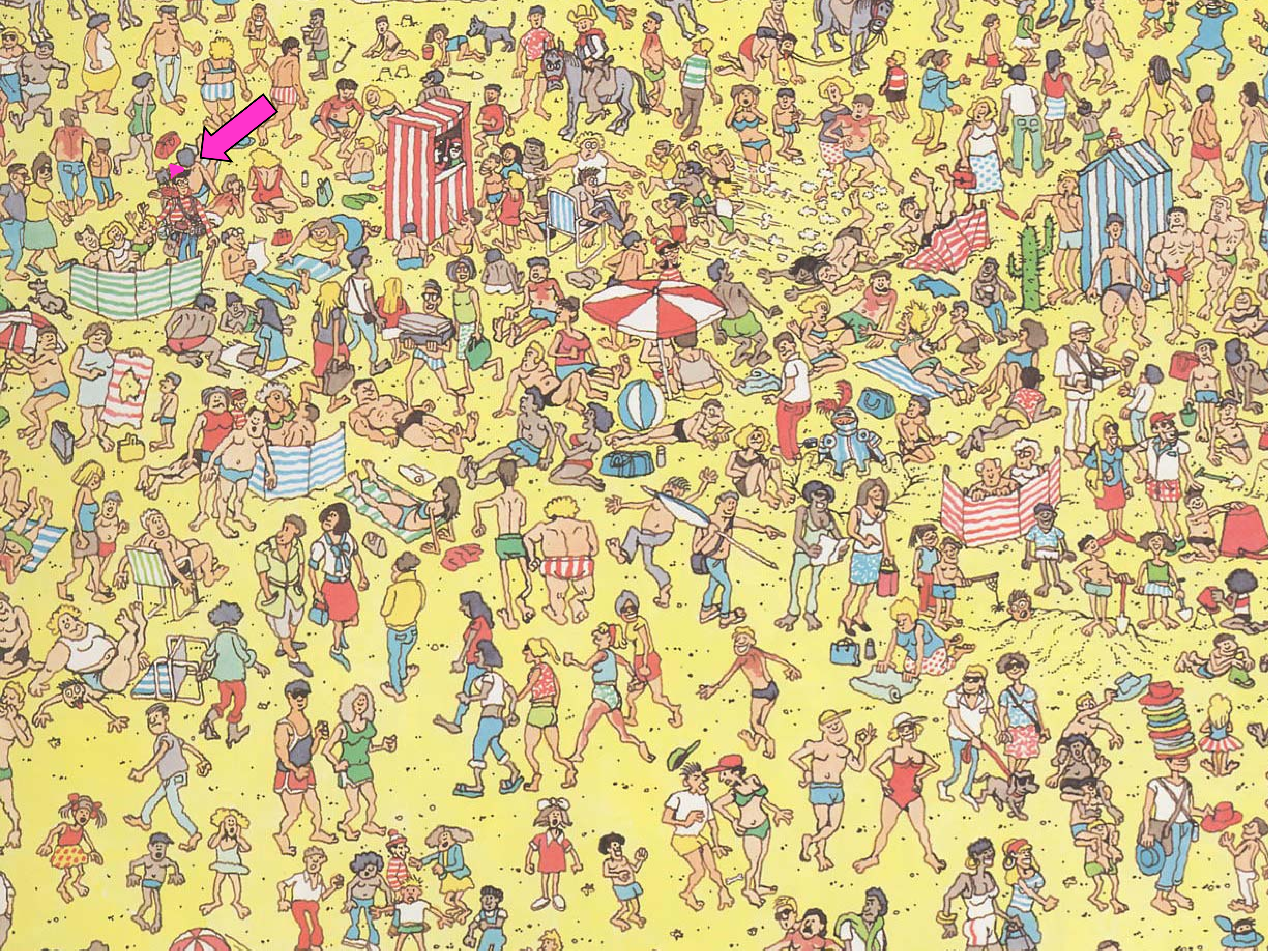
STM image of a Xe atom adsorbed on a Ni surface (110)





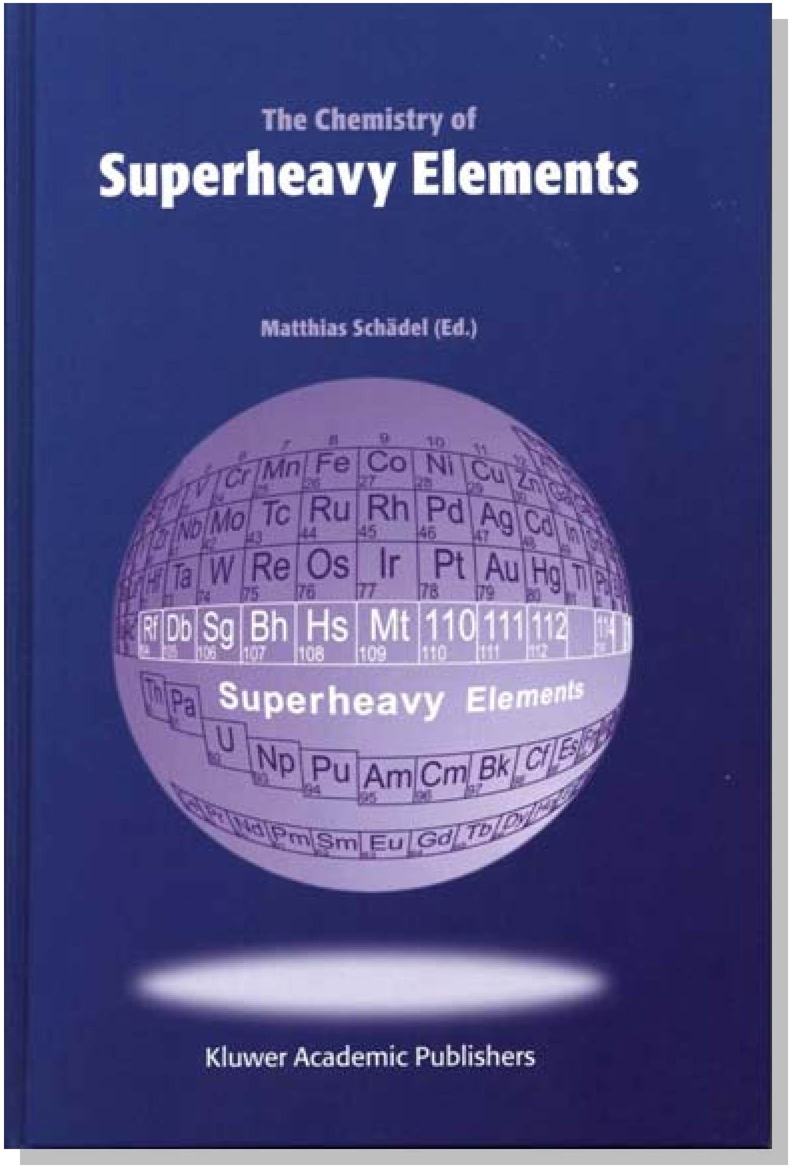
http://www.almaden.ibm.com/vis/stm/gallery.html

Chemistry of “one (exotic) atom at the time”?

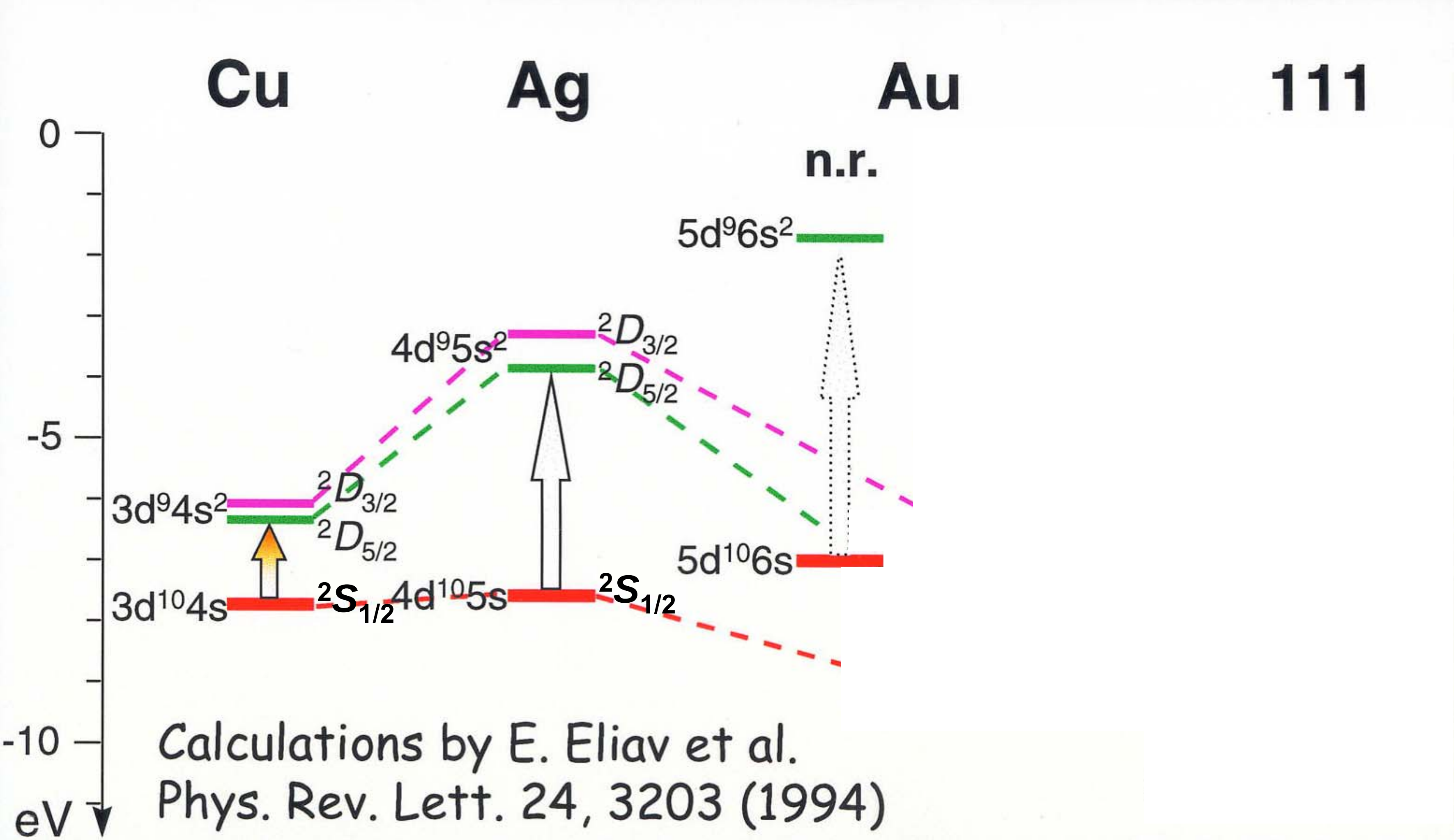


Current status of superheavy element chemistry:

Read the book!



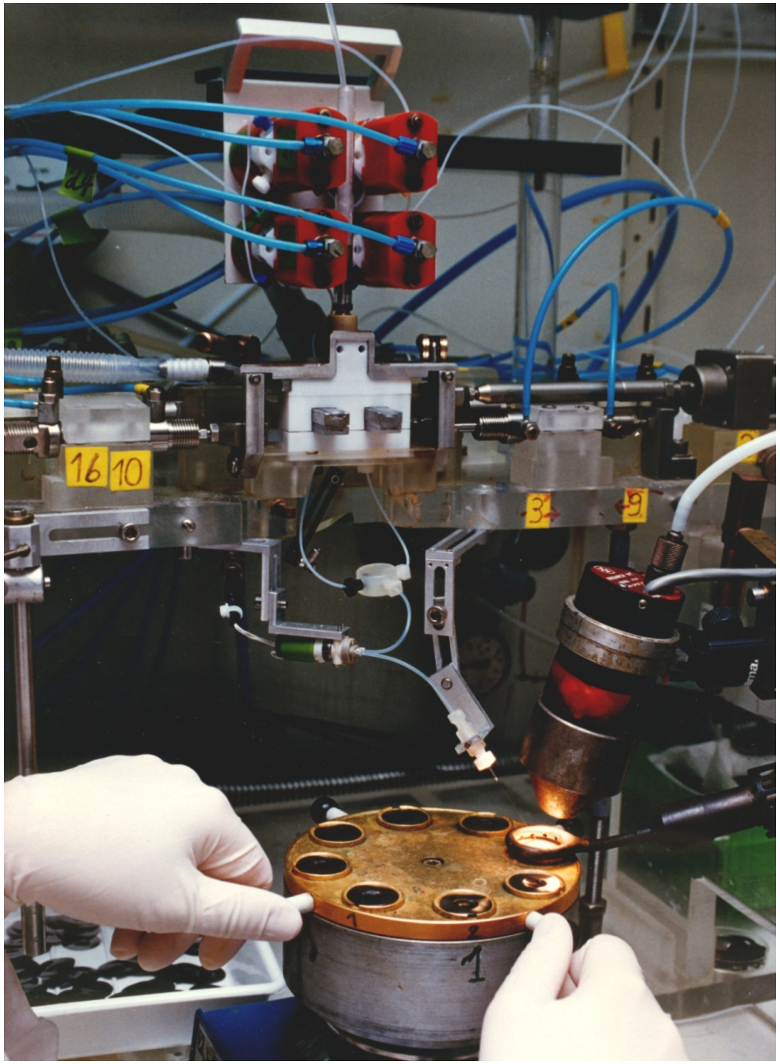
Relativistic effects: the color of gold!



Aqueous chemistry of Dubnium (*Z*=105)

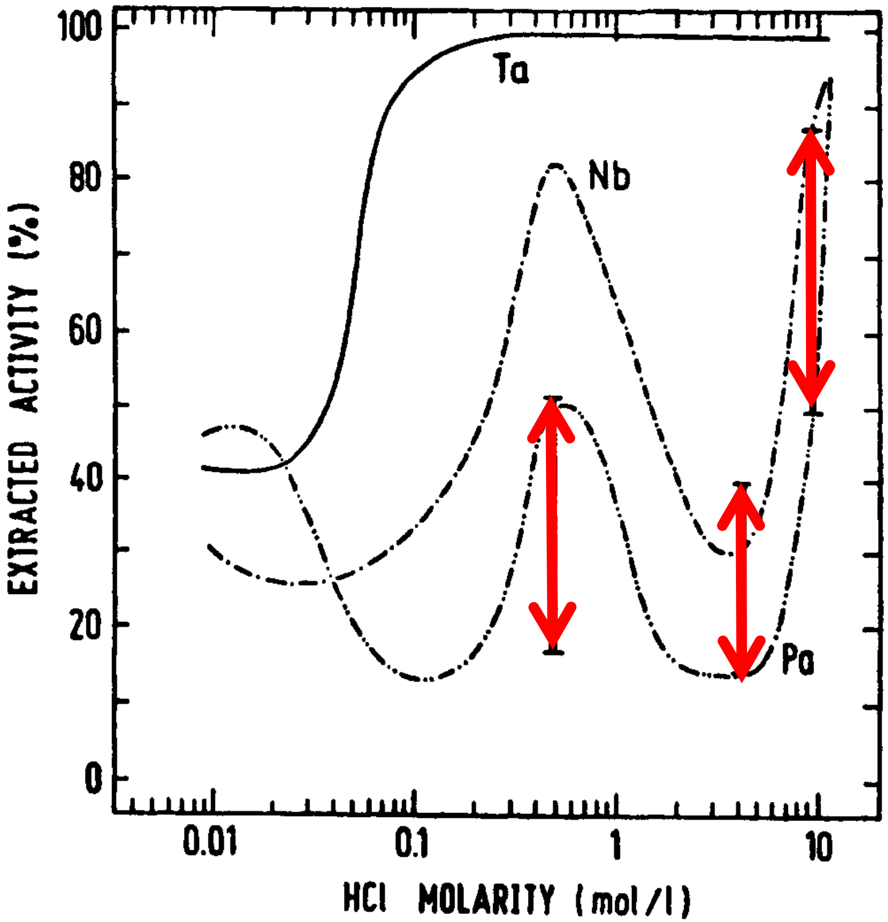
Investigated with the
Automated **R**apid **C**hemistry **A**pparatus
ARCA

J.V. Kratz & M. Schädel et al.,



Non Ta-like behavior of Dubnium

H.P. Zimmermann et al., RCA 60, 11 (1993)



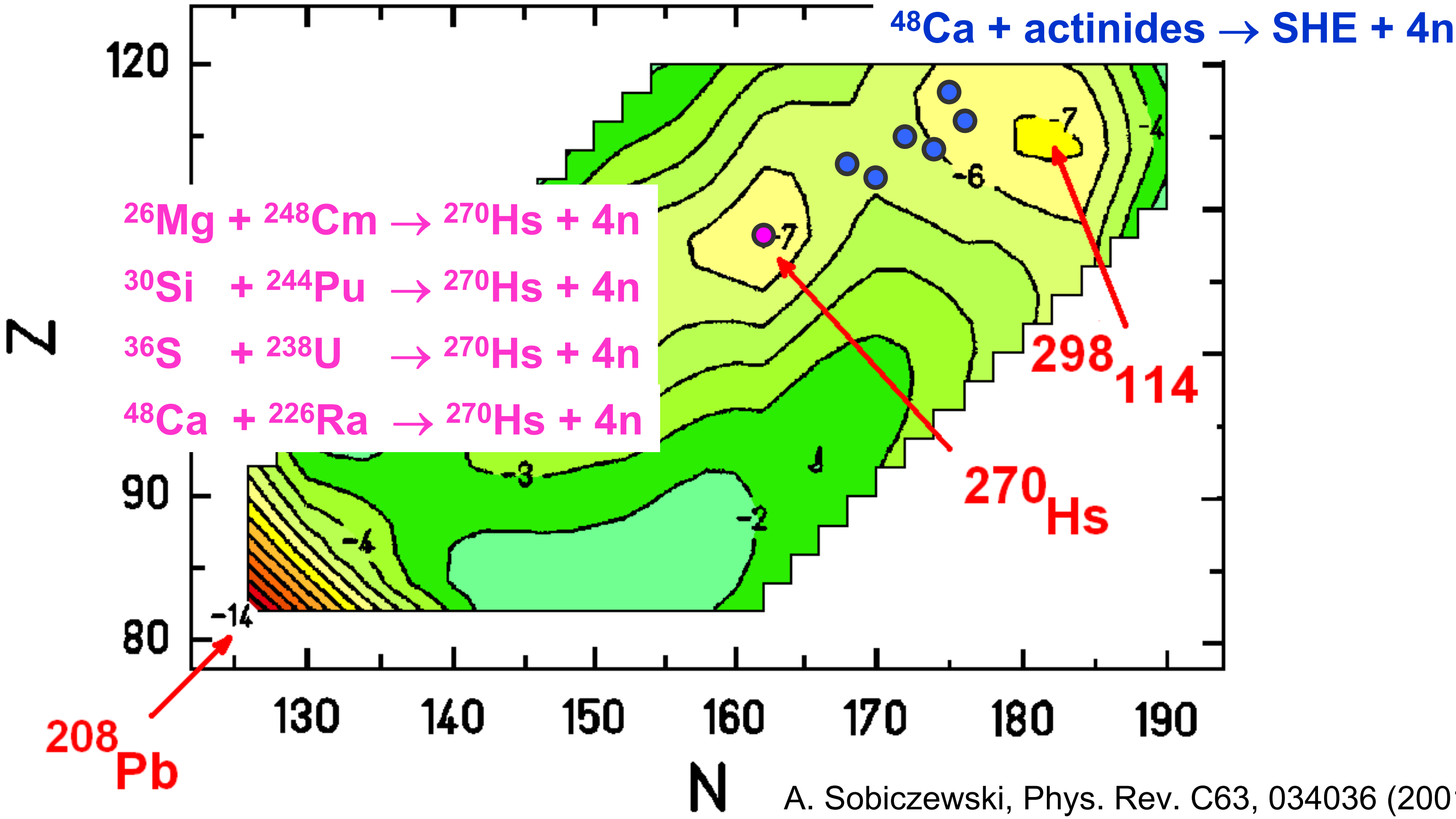
Precentage extractet activity of Nb, Ta, and Pa tracers (curves) as a function of HCl concentration in the System TiOA-HCl/0.03 M HF. The bold bars encompass the upper and lower limits deduced for the Db extraction from the elution positions in the chromatography experiments. The complete extraction of Db into TiOA from 12 M HCl / 0.02 M HF ist not indicated for clarity.

Hassium (*Z*=108)

- Named after the German Bundesland Hessen
- Discovered at Gesellschaft für Schwerionenforschung (GSI) 1984
- First chemical investigation: C.E. Düllmann et al., Nature 418, 859 (2002)

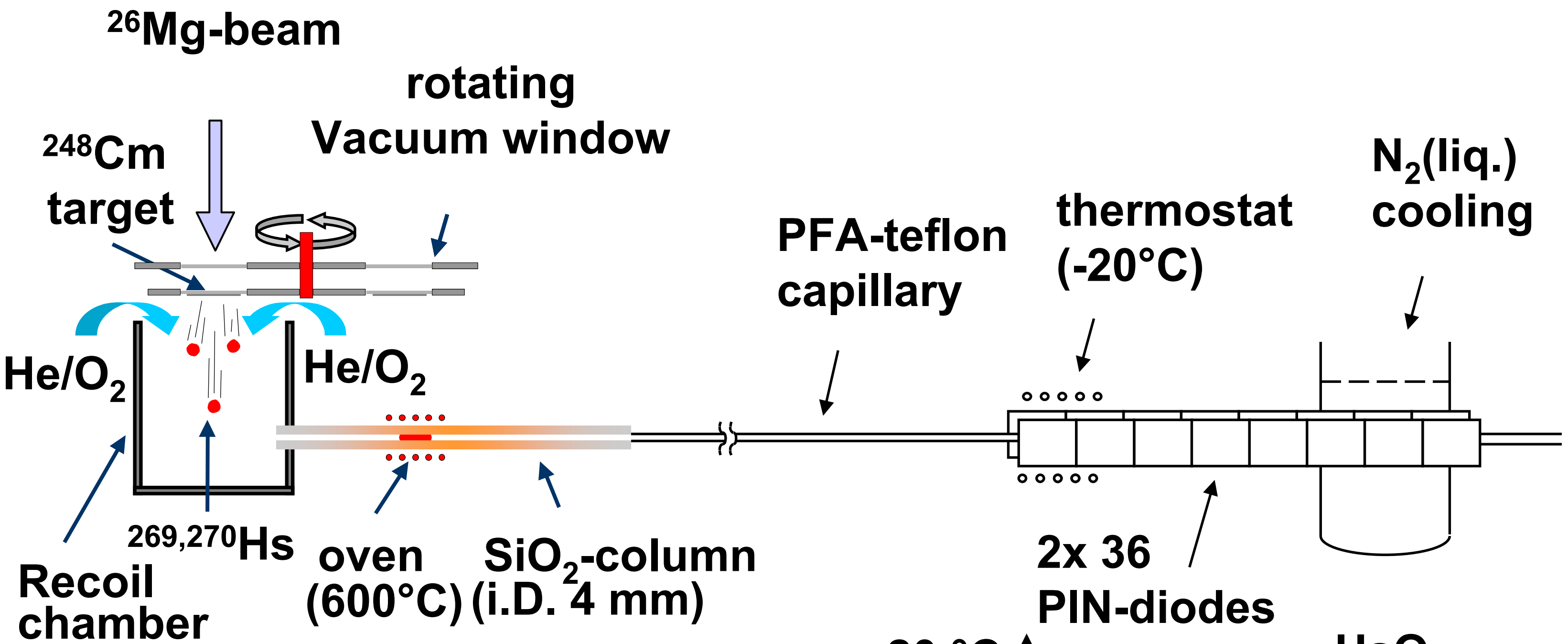
Understanding Superheavy Element Synthesis

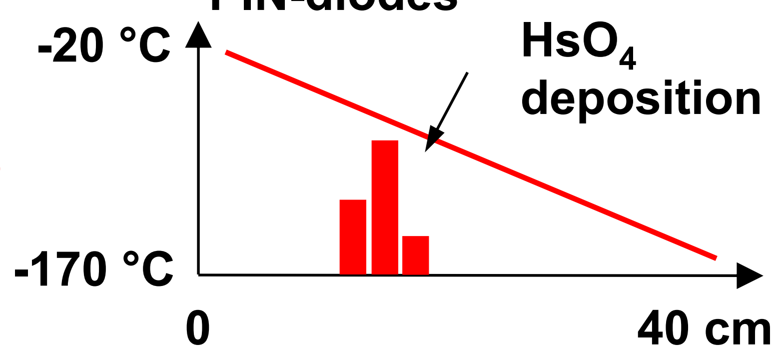
Shell correction energies for nuclides with Z≥82 and N≥126



A. Sobiczewski, Phys. Rev. C63, 034036 (2001)

Chemistry: a highly efficient Hassium separator





Overall Efficiency for ^{269}Hs: 55%

Detection system COMPACT

Cryo

On-line

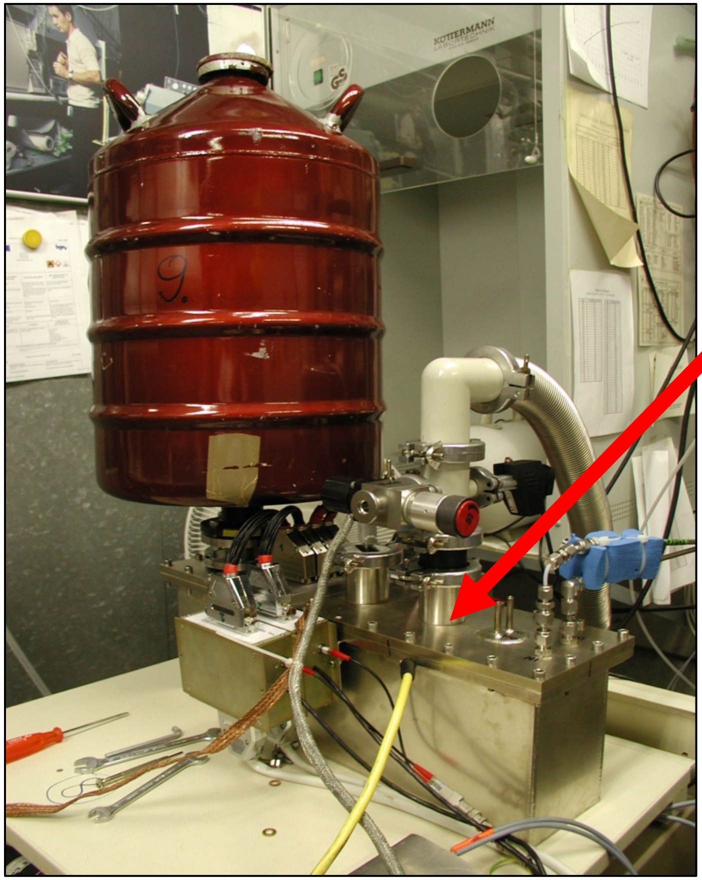
Multidetector for

Physics

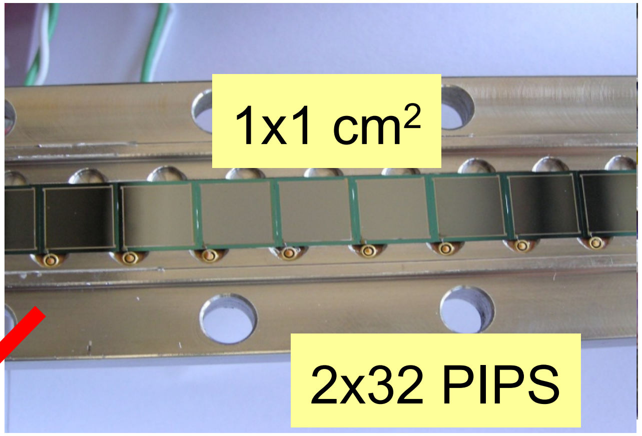
And

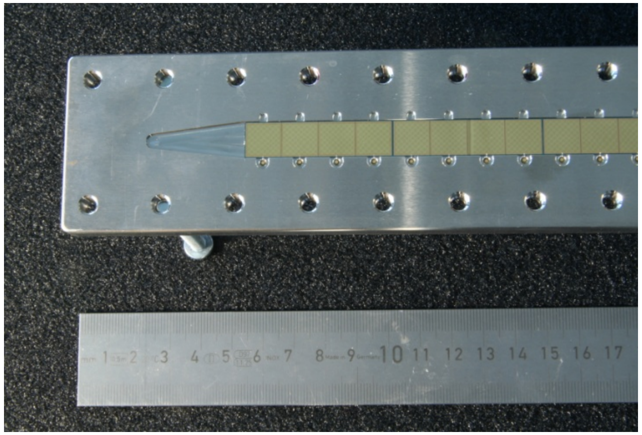
Chemistry of

Transactinides



Version 1: 78% detection eff.





Version 2: 93% detection eff.

Observed Nuclides

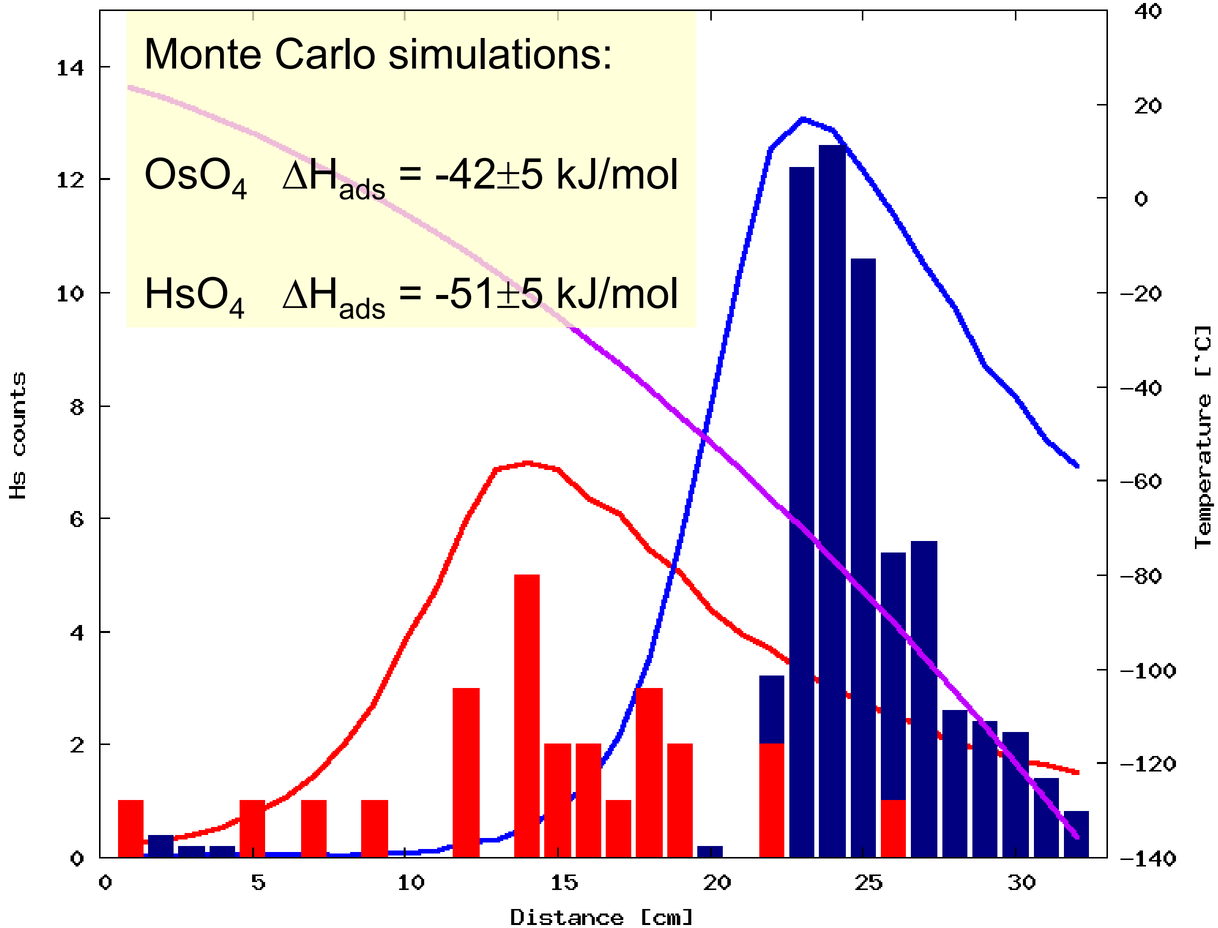
Number of decay chains: 13 7 6

5 new nuclides!

* T_α is calculated from measured Q_α using phenomenological formula from
A. Parkhomenko, A. Sobiczewski,
Acta Physica Polonica 36, No. 10 (2005)

^{270}Hs: Jan Dvorak *et al.*, Physical Review Letters **97**, 242501 (2006)
^{271}Hs: Jan Dvorak *et al.*, Physical Review Letters **100**, 132503 (2008)

Thermochromatography of HsO_4



Element 112 production

$^{245}Cm(^{48}Ca, 2n)\,^{291}116$ →

$^{291}116$
18 ms
10.74 MeV

$^{242}Pu(^{48}Ca, 3n)\,^{287}114$ →

$^{287}114$
0.48 s
10.02 MeV

$^{238}U(^{48}Ca, 3n)\,^{283}112$ →

$^{283}112$
3.8 s
9.54 MeV

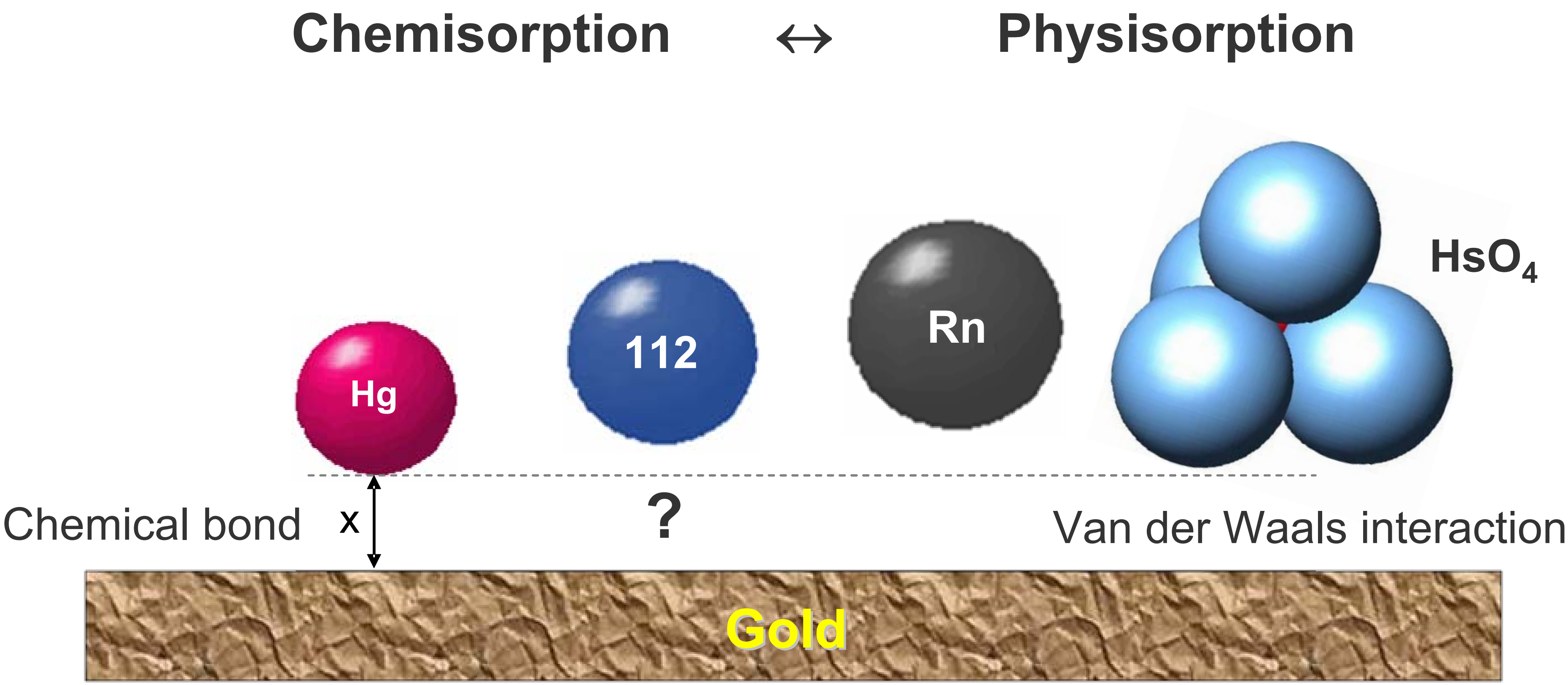
^{279}Ds
0.20 s
SF(>90%)
205 MeV

PAUL SCHERRER INSTITUT PSI

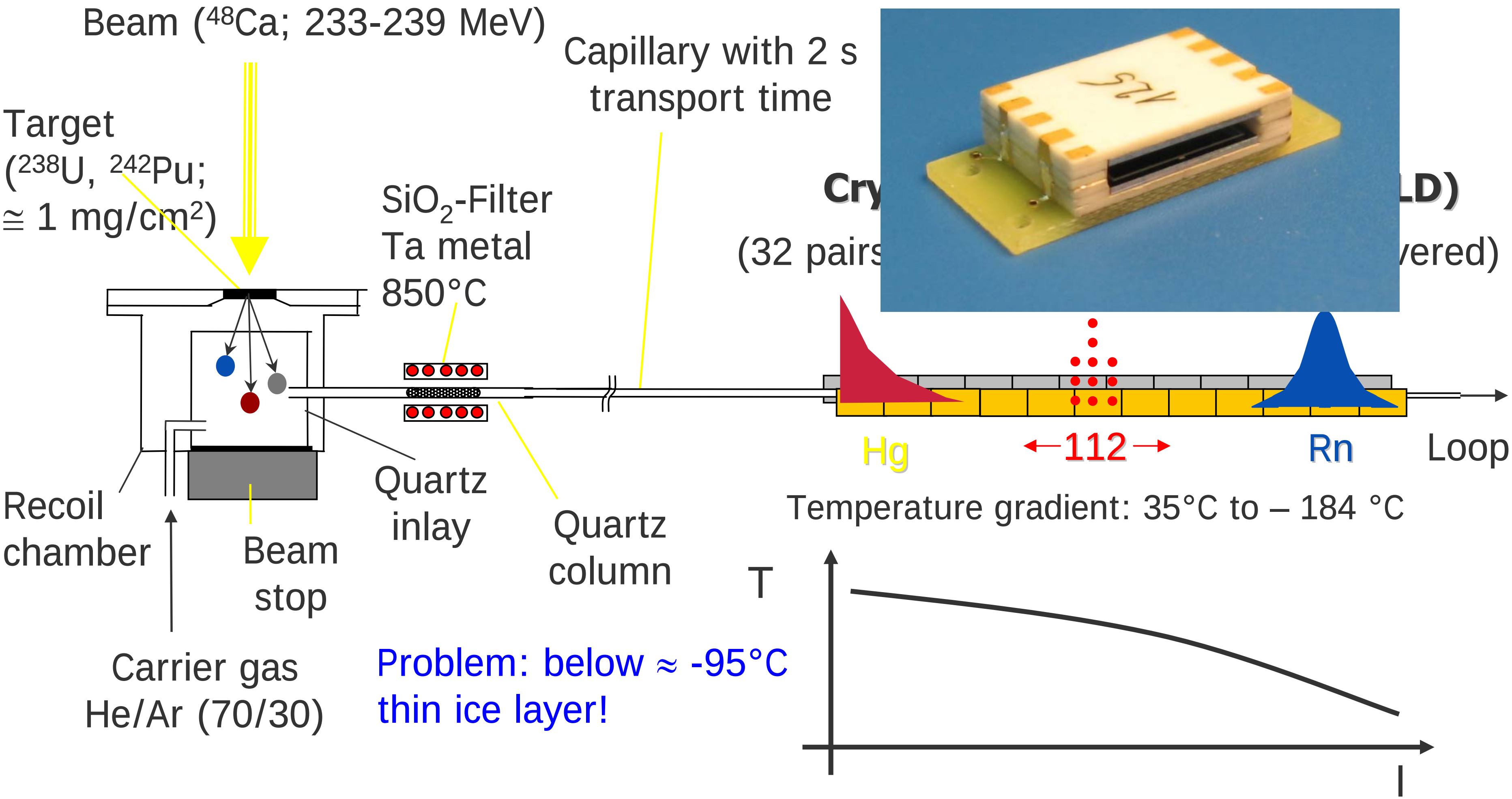
UNIVERSITÄT BERN

Yu.Ts. Oganessian,
J. Phys. G: Nucl. Part. Phys. **34** (2007) R165–R242

Experimental approach



The element 112 experiment
(IVO Technique)



NUCLEAR CHEMISTRY

Panning for ununbium

Andreas Türler

The chemical identification of two atoms of element 112 — scooped from the helium stream they were suspended in using a gold pan — brings the superheavy elements' fabled island of stability into sharper focus.

UNDERWOOD & UNDERWOOD/CORBIS

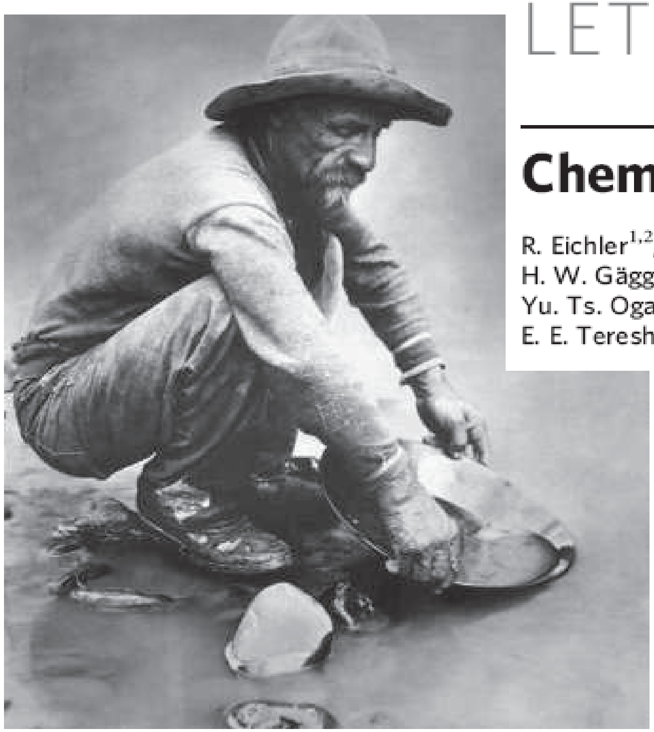


Figure 1 | Element panning, old-school style.

LETTERS

Chemical characterization of element 112

R. Eichler[1,2], N. V. Aksenov[3], A. V. Belozerov[3], G. A. Bozhikov[3], V. I. Chepigin[3], S. N. Dmitriev[3], R. Dressler[1], H. W. Gäggeler[1,2], V. A. Gorshkov[3], F. Haenssler[1,2], M. G. Itkis[3], A. Laube[1], V. Ya. Lebedev[3], O. N. Malyshev[3], Yu. Ts. Oganessian[3], O. V. Petrushkin[3], D. Piguet[1], P. Rasmussen[1], S. V. Shishkin[3], A. V. Shutov[3], A. I. Svirikhin[3], E. E. Tereshatov[3], G. K. Vostokin[3], M. Wegrzecki[4] & A. V. Yeremin[3]

Vol 447 | 3 May 2007 | doi:10.1038/nature05761

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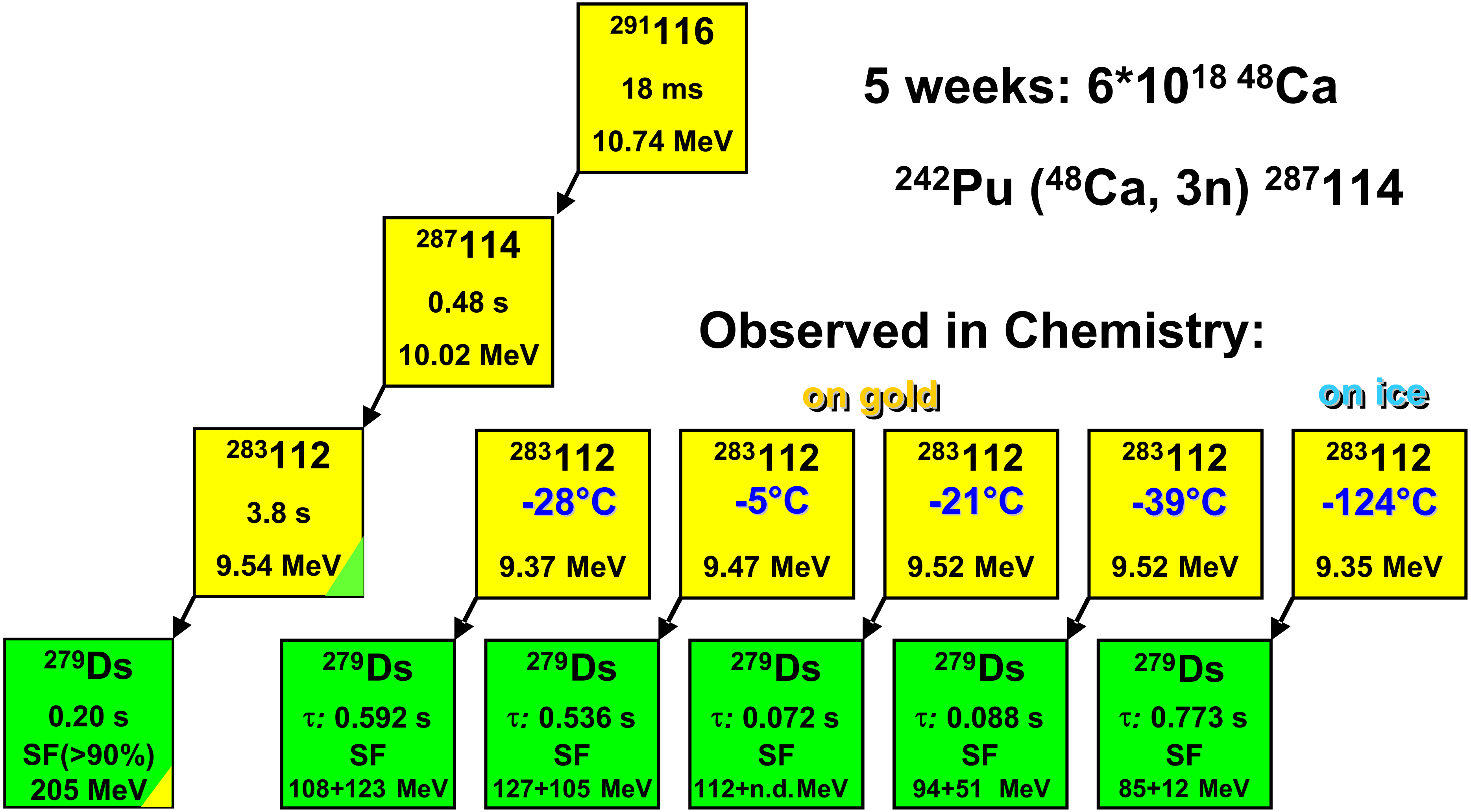
Observed decay chains: Dubna 2006/2007

5 weeks: $6 \cdot 10^{18}$ ^{48}Ca

^{242}Pu (^{48}Ca, 3n) $^{287}114$

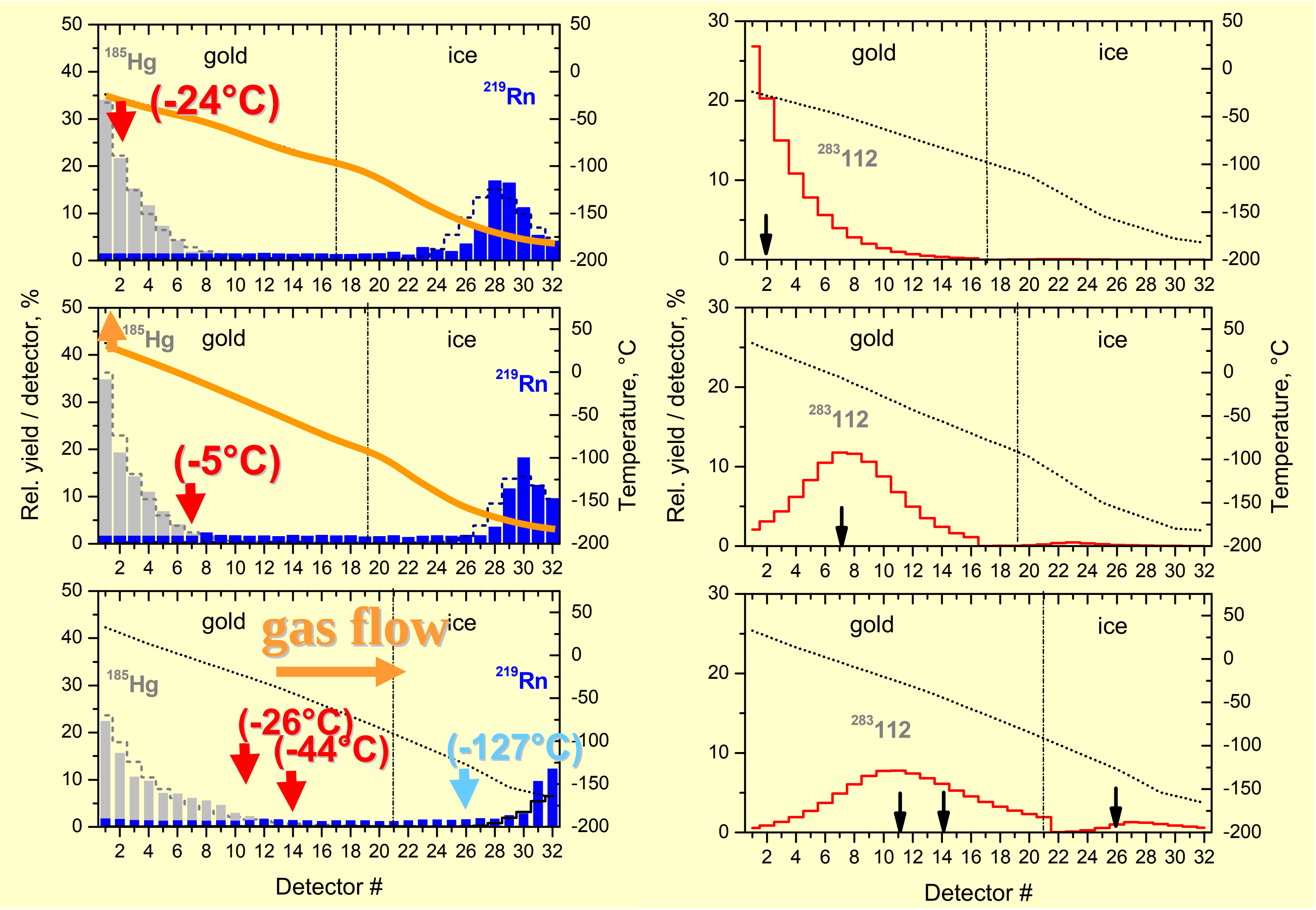
Observed in Chemistry:



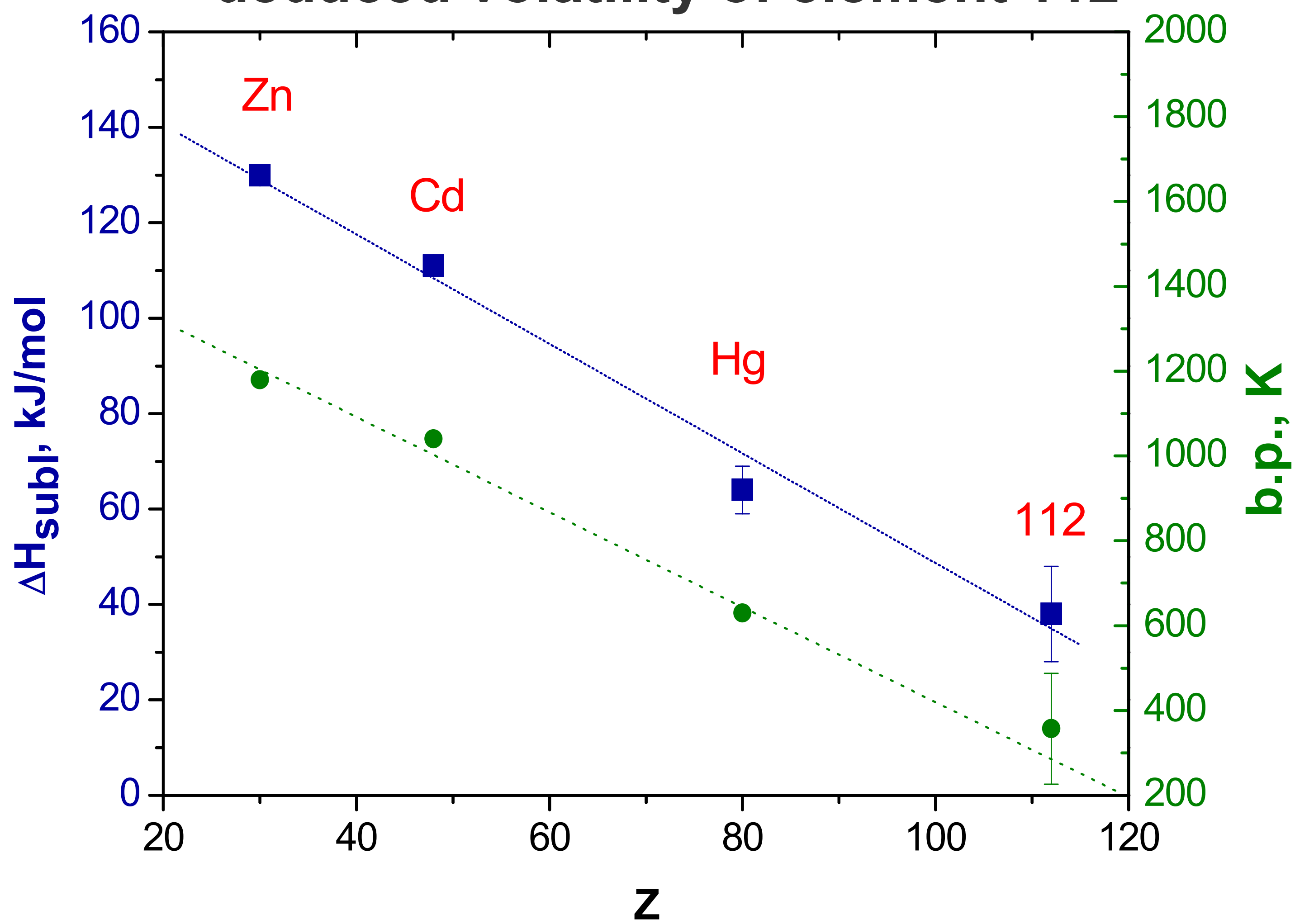
R. Eichler et al. TAN07 and Angew. Chem. Int. Ed. 2008, 47, 3262 –3266

Experiment

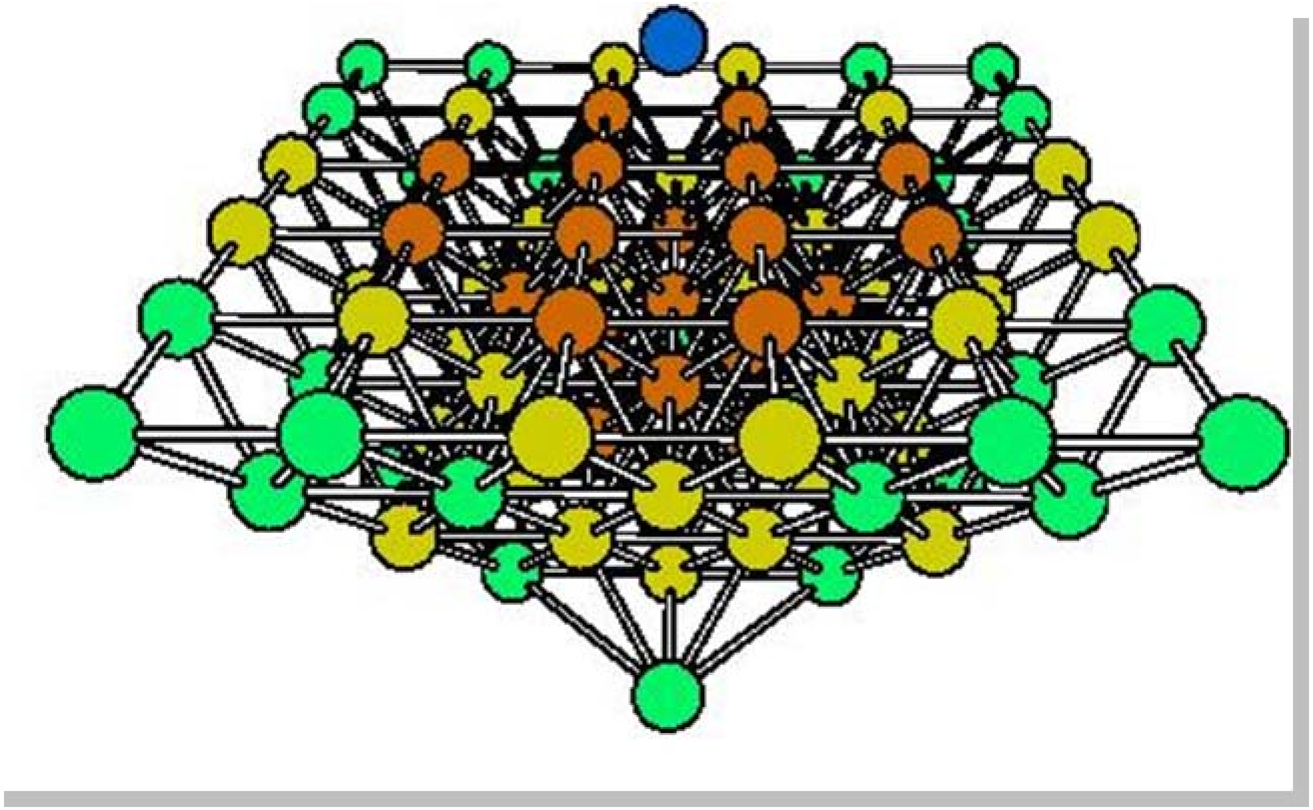
Model calculation



From experimental results deduced volatility of element 112



(E112) ad-atom on the embedded gold cluster

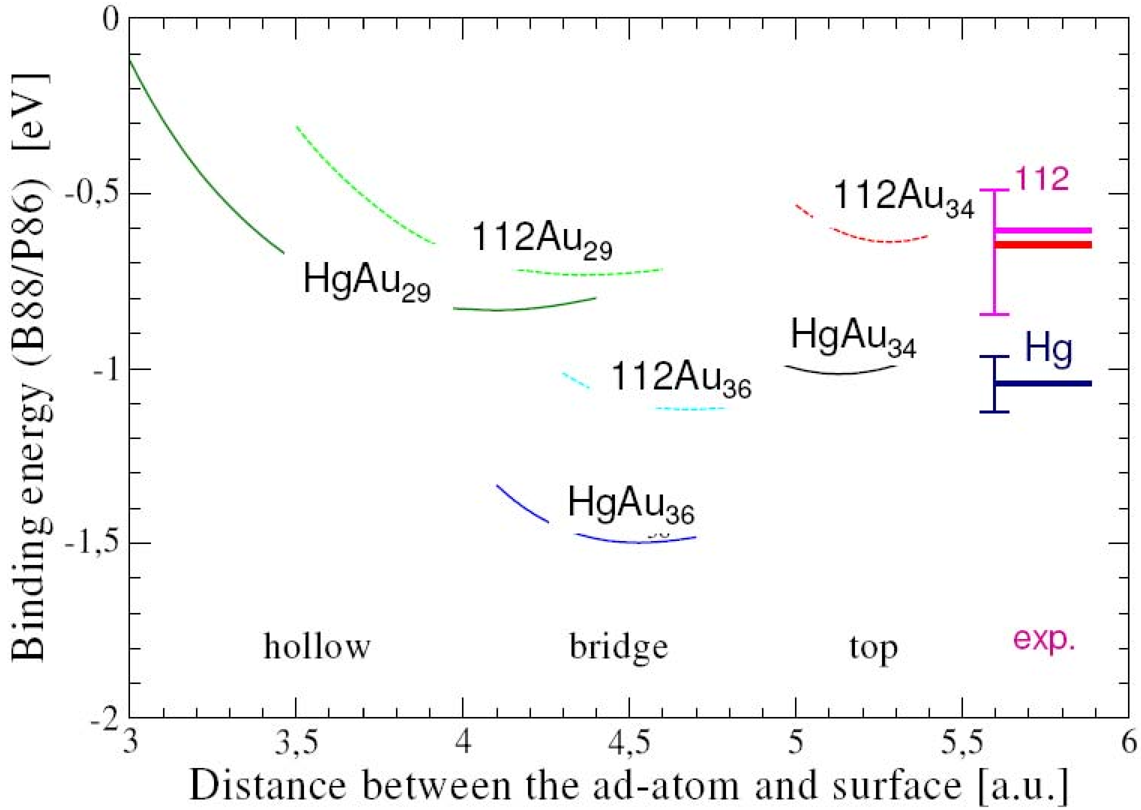


≈ 35 Au-cluster atom explicitly treated and ≈ 100 Au atoms averaged

C. Sarpe-Tudoran et al., Eur. Phys. J D 24 (2003) 65
V. Pershina et al., Nucl. Phys. A734 (2004) 200

Results of Embedded Cluster Calculations

V.G. Pershina et al., contribution to TASCA´08 workshop



C. Sarpe-Tudoran *et al.* J. Chem. Phys. **126**, 174702 (2007)]

112

Predicted:

T_{ads}(calc.) = 0 °C

ΔH_{ads}(calc.) = - 62 kJ/mol

[V. Pershina *et al.*, Nucl. Phys. A **734**, 200 (2004); *ibid* **787**, 381 (2007)]

Observed:

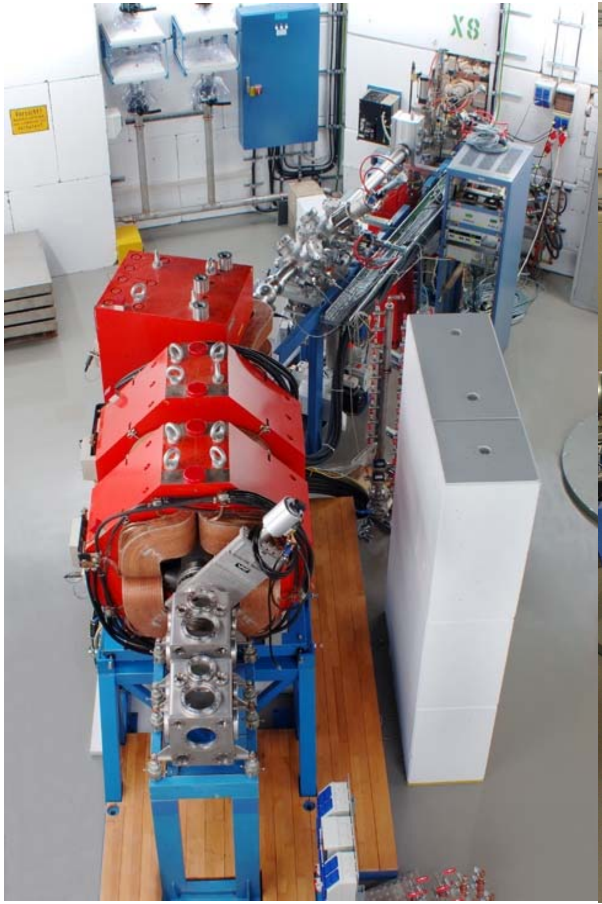
T_{ads}(exp.) = -5 °C

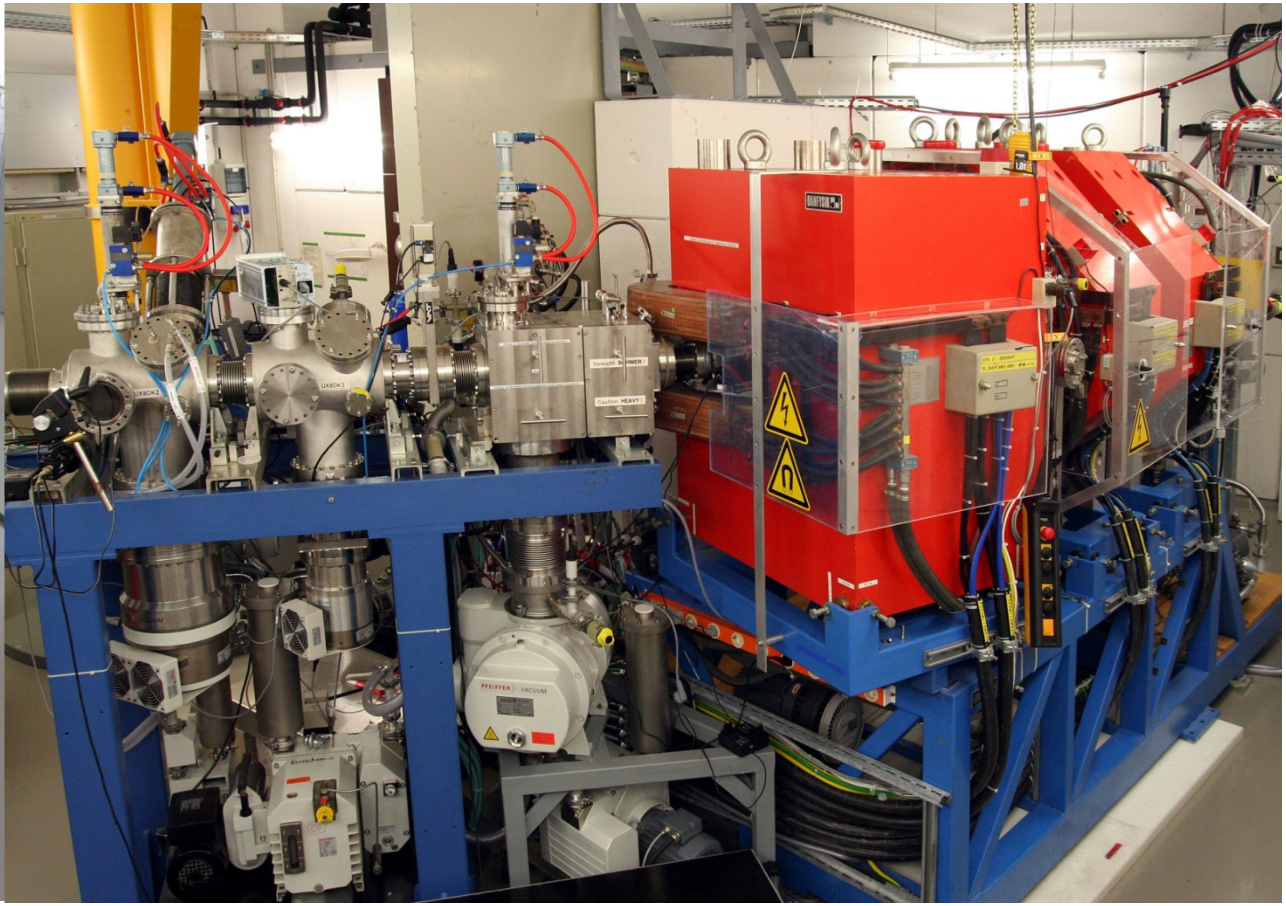
ΔH_{ads}(exp.) = -52_{-4}^{+20} kJ/mol

[R. Eichler, *et al.* Nature, **447**, 72 (2007)]

Future of transactinide chemistry: TASCA

TASCA - Trans Actinide Separator and Chemistry Apparatus





TASCA home page: http://www-w2k.gsi.de/tasca/

TASCA collaboration

magnets, power supplies, vacuum chambers and pumps, construction of cave and shielding, beam line, crane, electronics, €'s

magnetic field maps, ion optics, Monte-Carlo simulations, control system, differential pumping system, vacuum windows, focal plane detector & electronics, €'s

targets, recoil chamber HTM, €'s

recoil chamber SIM, €'s

Monte Carlo simulations, ion optics, TOF

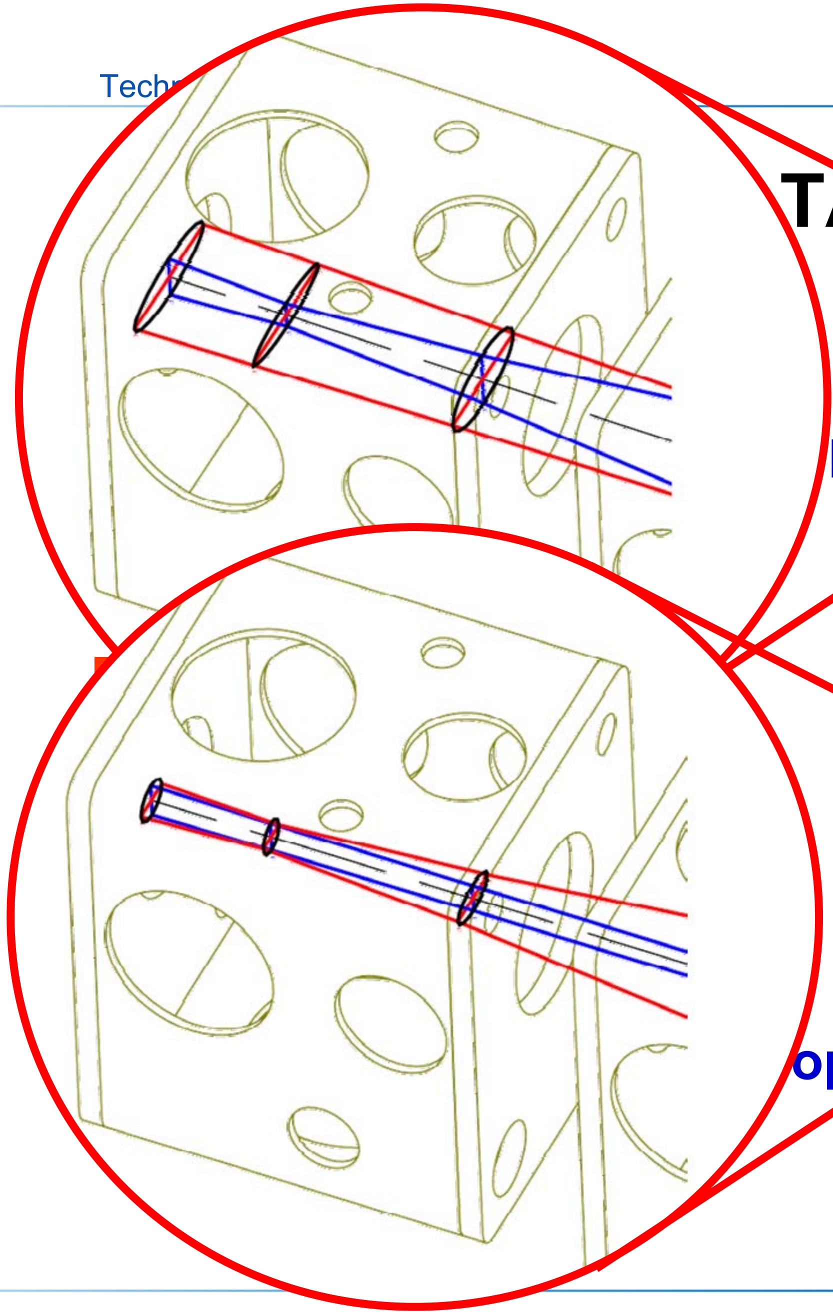
Monte Carlo simulations, ion optics, electronics

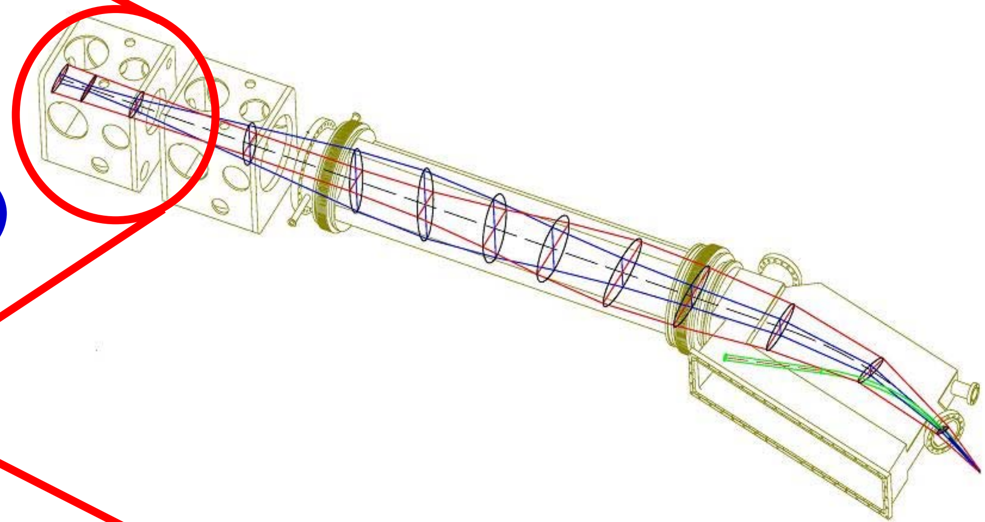
differential pumping system, ion optics, focal plane detector

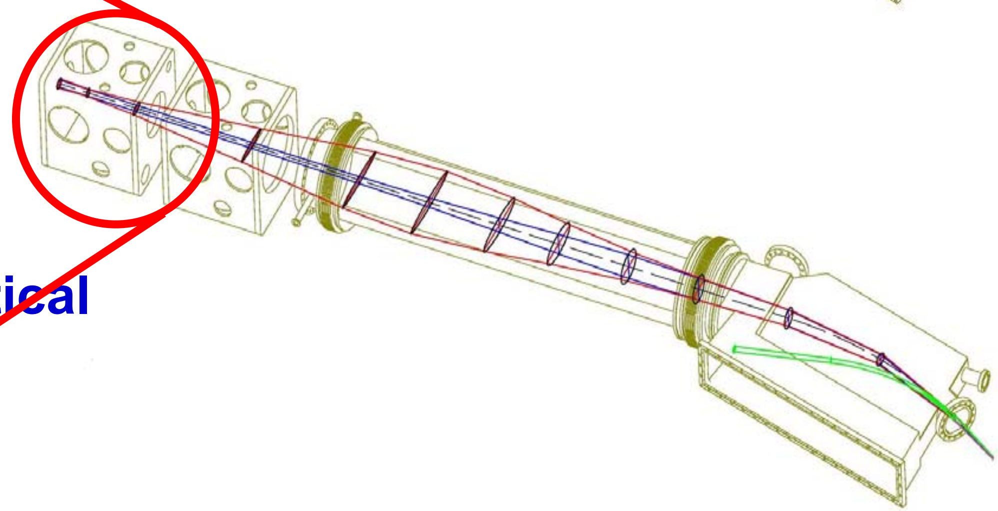
TASCA vacuum chambers

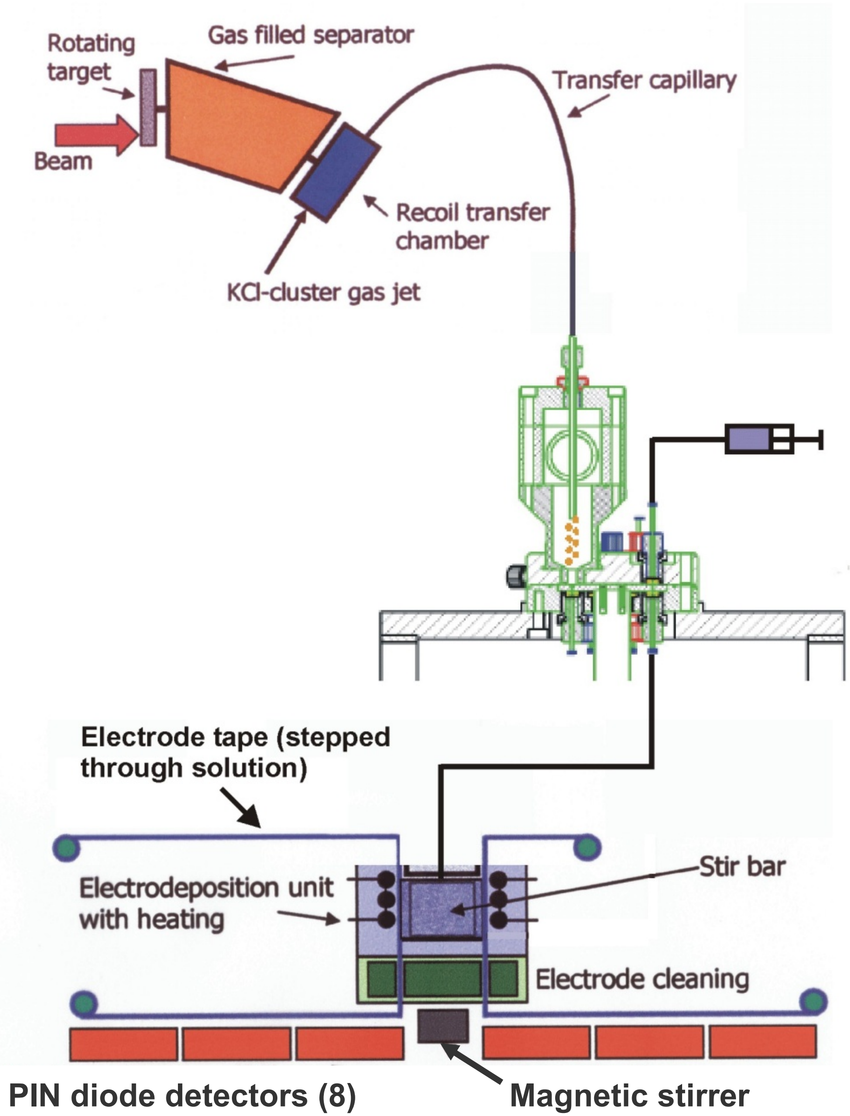
M)

optical









An example of a future electrodepostion experiment with Hassium

Coupling scheme of

TASCA – RTC – ALOHA – ELECTRODEPOSITION with two electrode tapes and two detector arrays

The End!

(of the talk)

Thank you for listening